3.1 Nutrients

Nutrients need to be applied to most fields to maintain high crop yield. Most nutrients applied are from commercial fertilizer. Commercial fertilizer use in the United States has declined from a peak in 1981 because of fewer planted acres and stable or falling application rates. Fertilizer prices paid by farmers were relatively stable from 1989 to 1993, but increased dramatically in 1994 and 1995.

Contents

Crops take up nutrients—primarily nitrogen (N); phosphate ($P_2 0_5$), the oxide form of phosphorus (P); and potash ($K_2 0$), the oxide form of potassium (K)—from the soil as they grow (see Glossary for more on the roles of nutrients in food and fiber production). Plants require other nutrients than nitrogen, phosphate, and potash, but in smaller amounts. Magnesium, calcium, and sulphur are also essential nutrients for plant growth and development. Sulphur, for example, is important to plants for protein formation. Nutrients that plants need in only small or trace amounts (called micronutrients) include boron, chlorine, copper, iron, manganese, molybdenum, cobalt, sodium, and zinc. Commercial fertilizers are applied by farmers to ensure sufficient nutrients for high yields.

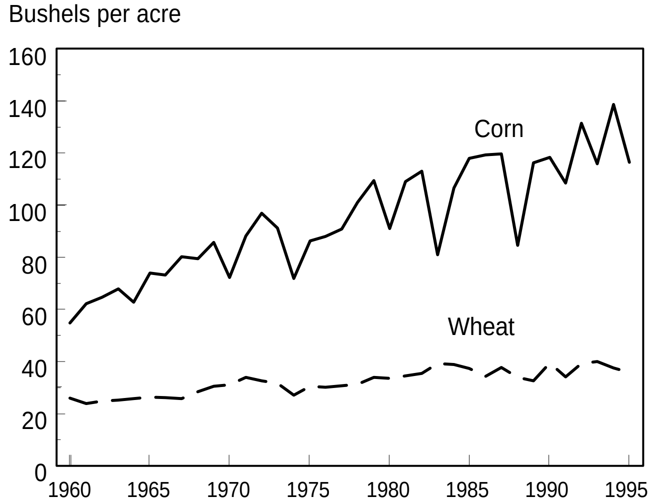
Lime is also applied to some soils as a soil conditioner, rather than as a nutrient. Lime reduces soil acidity (pH) so that crops can better utilize available nutrients and micronutrients.

From the settlement of the United States until the 19th century, increased food production came almost entirely from expanding the cropland base and mining the nutrients in the soil. However, the expanding demand for agricultural commodities required soil nutrient replacement to maintain or expand crop yields. First, manure and other farm refuse were applied to the soils. Later, applications of manure were supplemented with fish, seaweed, peatmoss, leaves, straw, leached ashes, bonemeal, and Peruvian guano, materials that contained a higher percentage of nitrogen, phosphate, and potash than did manure (Wines, 1985). As manufacturing developed, production of chemical fertilizers like superphosphates and, later, urea and anhydrous ammonia (see Glossary) replaced most fertilizers produced from recycled wastes. Commercial fertilizers provided low-cost nutrients to help realize the yield potential of new crop varieties and hybrids (Ibach and Williams, 1971). Since 1960, yields per unit of land area for major crops have increased dramatically. For example, average corn yield has increased from 55 bushels per acre in 1960 to 139 bushels in 1994 and average wheat yield from 26 to 38 bushels per acre (fig. 3.1.1). If nutrients were not applied, today's crops would rapidly deplete the soil's store of nutrients and yields would plummet.

Nutrient Sources

Commercial fertilizer is by far the major source of applied plant nutrients in the United States, followed by animal manure. Treated or composted municipal and industrial wastes are applied as sources of plant nutrients in some areas, but little data are available and overall use is likely limited, although increasing. Specific aspects of these three sources of nutrients are described in the following sections.

Figure 3.1.1--Average corn and wheat yields per harvested acre, 1960-95



Source: USDA, ERS, based on Agricultural Statistics, 1994 and earlier issues; and ERS, Agricultural Outlook, 1995.

Commercial Fertilizer

The U.S. commercial fertilizer industry is essentially composed of three separate industries (nitrogen, phosphate, and potash). Each has different material and process requirements but both are horizontally and vertically integrated (Andrilenas and Vroomen, 1990).

Anhydrous ammonia is the source of nearly all nitrogen fertilizer. It may be applied directly to the soil or converted into other nitrogen fertilizer such as ammonium nitrate, urea, nitrogen solutions, synthetic ammonium sulfate, and ammonium phosphate. Anhydrous ammonia is synthesized through a chemical process that combines atmospheric nitrogen with hydrogen. Nitrogen can be obtained from the air, but the hydrogen is derived from natural gas.

U.S. capacity to produce anhydrous ammonia and other nitrogen fertilizers increased since 1950 in response to rising demand. Capacity increased from 7.8 million tons in 1964 to 20 million tons in 1981, but has declined to about 17 million tons due to plant closures and lack of new plant construction (International Fertilizer Development Center, 1995). Plants built before 1960 were scattered around the country in areas of high market demand. However, plants built since then are located near natural gas regions of the Delta (Mississippi, Arkansas, and Louisiana) and the Southern Plains (Texas and Oklahoma).

The United States is a net importer of nitrogen. In 1995, the United States exported more than 3 million nutrient tons of nitrogen and imported over 5 million nutrient tons; however, imports are understated because anhydrous ammonia imports from the former Soviet Union are not reported by the Department of Commerce due to a disclosure claim. The major fertilizer import is anhydrous ammonia while the major export is diammonium phosphate, which contains nitrogen.

Nearly all phosphate fertilizer is produced by treating phosphate rock with sulfuric acid to produce phosphoric acid, which is further processed into various phosphatic fertilizer materials such as superphosphates and diammonium phosphates. The United States has become the world's largest phosphate fertilizer exporter. Approximately 3.3 tons of phosphate rock and about 2.8 tons of sulfuric acid are required to produce a ton of phosphate fertilizer. U.S. annual phosphoric acid capacity is over 14 million tons. Phosphate rock is obtained from mines mainly in Florida and North Carolina, with annual capacity estimated at 65 million tons.

Potash can be used as a fertilizer with less processing or refining than nitrogen or phosphate. Most potash deposits in the United States are located near Carlsbad, New Mexico. However, these deposits supply less than 10 percent of U.S. demand. Vast potash deposits in Saskatchewan and New Brunswick, Canada are cheaper to mine than the dwindling U.S. reserves because of the large size, uniformity, and high quality of the Canadian deposits, and the modern mining techniques used. The United States currently imports over 5 million tons of potash and over 95 percent of these imports come from Canada. U.S. and Canadian annual potash capacity is about 1.6 and 13.9 million tons, respectively.

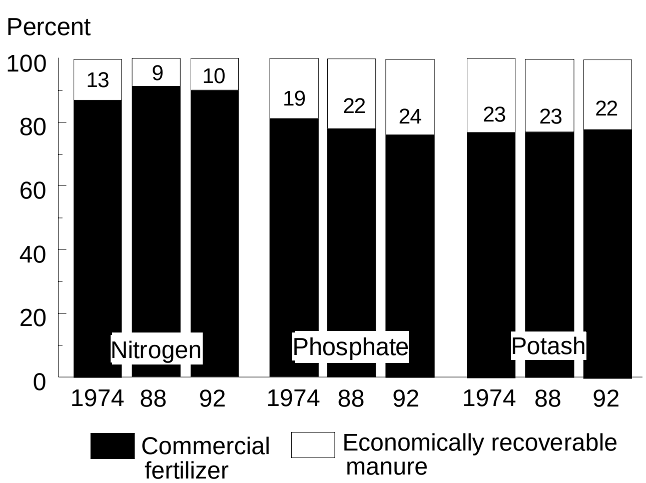
Calcium, magnesium, and sulfur are often added to soils to correct plant conditions such as empty peanut shells due to the failure of fruit to develop, failure of new emerging corn leaves to unfold, yellowing between veins of older leaves, and pale yellow or light green leaves. Applying lime to bring soil pH into proper range for optimum plant growth usually supplies sufficient calcium. Primary sources of calcium are the liming materials and gypsum, which are considered soil amendments rather than fertilizers. The most common source of magnesium is dolomite limestone, which contains up to 12 percent magnesium (Fertilizer Institute, 1982). The main forms of sulfur in soil are inorganic sulfates and sulfur in organic matter. Atmospheric sulfur dioxide had been a major source of sulfur for crops, but as atmospheric emissions of sulfur dioxide are reduced by environmental controls the sulfur needs of crops must be supplied by fertilizer sources. Sulfuric acid, a byproduct in phosphate fertilizer manufacturing, provides an adequate amount of sulfur for many crop needs.

Availability of micronutrients to plants is related to soil pH. Availability of boron, copper, iron, manganese, and zinc generally decrease as soil pH increases from 5 to 7; availability of molybdenum increases. Micronutrients are involved in cell division, photosynthesis, fruit formation, carbohydrate and water metabolism, chlorophyll formation, protein synthesis, and seed development in plants. Micronutrient needs during different stages of plant growth must be better understood by both research scientist and farmer so that appropriate amounts are made available.

Animal Manure

Animal waste is primarily manure, but on some large poultry operations, dead chickens are also a disposal problem and a source of nutrients if properly composted. In recent years, animal wastes have provided 9-24 percent of total nutrients available for crop production (fig. 3.1.2). Actual application of animal wastes as nutrients is less than this (table 3.1.3). Because of transportation costs, use of animal

Figure 3.1.2--Availability of nutrients for application, 1974, 1988, and 1992



Source: USDA, ERS, based on U.S. EPA, 1979; USDA, unpublished data, 1977; and USDA, 1992.

waste as fertilizer is economically feasible only if onfarm or nearby sources exist, and thus occurs on relatively few acres.

In 1992, there were 435 million acres of cropland, of which 124 million or 28 percent were operated by farmers having confined animal units. These 511,000 farms had 60.7 million animal units of beef, dairy, swine, turkey, and poultry (Letson and Gollehon, 1996), producing an estimated 1.23, 1.32, and 1.44 million tons of economically recoverable nitrogen (N), phosphate (P_20_5), and potash (K_20). Letson and Gollehon (1996) also determined that large specialized animal production farms produce most animals but have little cropland. Facilities with fewer animals produce a minor share of the animals but have a large share of the cropland associated with confined livestock farms. Concentration of increasing numbers of animals on fewer farms has been a long-term trend (see fig.1.2.7 in chapter 1.2, *Land Tenure*). The significance of the shares of animals and acres is emphasized by the fact that around 90 percent of manure does not leave the farm where it is produced (Bosch and Napit, 1992). High-density areas like dairy farms in southern California, beef feedlots in the Southern Plains, large hog operations in the Corn Belt, and the broiler belt across the Delta, Southeast, and Appalachian States provide large quantities of manure that is likely underused as fertilizer. However, some areas have both high manure nutrient densities and high fertilizer spending per acre, suggesting redundant nutrient applications that may be an avoidable farming expense and that could impair water resources (Letson and Gollehon, 1996).

Environmental degradation, particularly of water, can occur from excessive use or improper handling or application of nutrients (Achorn and Broder, 1991; Bosch, Fuglie, and Keim, 1994; Kanwar, Baker, and Baker, 1988; and Kellogg, Maizel, and Goss, 1992: see also chapter 2.2, *Water Quality*). Large livestock operations are already under regulation as point sources of pollution, requiring installation of certain facilities and practices. In many critical areas, USDA is helping smaller livestock operations efficiently manage animal and commercial nutrients to reduce their loss to the environment (for more information, see chapter 4.5, *Nutrient Management*, and chapter 6.2, *Water Quality Programs*).

Municipal and Industrial Wastes

Municipal wastes include municipal solid wastes (MSW) and sewage sludge (SS). America's cities generated 200 million tons of MSW in 1990 (Millner and others, 1993). MSW includes paper and paperboard, glass, metals, plastics, rubber, leather, textile, wood, food wastes, yard trimmings, miscellaneous inorganic wastes, and other residential, institutional, and industrial wastes. The three major methods for MSW disposal in 1990 were land filling (61 percent), recoveries for recycling (17 percent), and incineration (12 percent). SS is collected at municipal wastewater plants. The three major methods of SS disposal in 1988 were land application (36 percent), surface water disposal (10) percent, and incineration (3 percent) (the rest of SS disposal is either not regulated or unknown). Agricultural land application was about 27 percent. A small portion (about 1.2 percent) of SS was used for composting in 1988. The number of municipal wastewater plants producing SS compost increased from 90 in 1983 to 318 in 1994 (Golstein and others, 1994). The outlets for SS compost are public works applications; wholesale marketing to soil blenders, landscapers, and nurseries; and give-away to the public.

The potential for agricultural use of municipal wastes is large, but a number of issues need resolution (see box, "Potential for Agricultural Use of Municipal Wastes," p. 111).

Commercial Fertilizer Use and Product Change, 1960-95

Commercial fertilizer use depends on a variety of factors including soil, climate, feasible technology, weather, crop mix, crop rotations, technological change, government programs, and commodity and fertilizer prices (Denbaly and Vroomen, 1993). Total fertilizer use has fluctuated with planted acreage because application rates and percentage of acres treated have been less variable than planted acreage.

U.S. nitrogen, phosphate, and potash use for all purposes rose from 7.5 million nutrient tons in 1960 to a record 23.7 million tons in 1981 (table 3.1.1). Total nutrient use has dropped from this level, along with total crop acreage, to 21.3 million nutrient tons.

Nitrogen, phosphate, and potash all contributed to the dramatic increase in fertilizer use during the 1960's and 1970's (table 3.1.1, fig. 3.1.3), although nitrogen use increased most rapidly. In 1960, nitrogen use was about 37 percent of total commercial nutrient use; by 1981, nitrogen use had increased 335 percent and represented over 50 percent of total commercial nutrient use. Nitrogen use equaled 11.7 million tons in 1995, or 55.2 percent of total commercial nutrient use. This relative gain in nitrogen use is the result of

Table 3.1.1—U.S. commercial fertilizer use, 1960-95[1]

Year ending June 30[2]	Total fertilizer materials3	Primary nutrient use			
		Nitrogen (N)	Phosphate (P_2O_5)	Potash (K_2O)	Total[4]
		Million tons			
1960	24.9	2.7	2.6	2.2	7.5
1961	25.6	3.0	2.6	2.2	7.8
1962	26.6	3.4	2.8	2.3	8.4
1963	28.8	3.9	3.1	2.5	9.5
1964	30.7	4.4	3.4	2.7	10.5
1965	31.8	4.6	3.5	2.8	10.9
1966	34.5	5.3	3.9	3.2	12.4
1967	37.1	6.0	4.3	3.6	14.0
1968	38.7	6.8	4.4	3.8	15.0
1969	38.9	6.9	4.7	3.9	15.5
1970	39.6	7.5	4.6	4.0	16.1
1971	41.1	8.1	4.8	4.2	17.2
1972	41.2	8.0	4.9	4.3	17.2
1973	43.3	8.3	5.1	4.6	18.0
1974	47.1	9.2	5.1	5.1	19.3
1975	42.5	8.6	4.5	4.4	17.6
1976	49.2	10.4	5.2	5.2	20.8
1977	51.6	10.6	5.6	5.8	22.1
1978	47.5	10.0	5.1	5.5	20.6
1979	51.5	10.7	5.6	6.2	22.6
1980	52.8	11.4	5.4	6.2	23.1
1981	54.0	11.9	5.4	6.3	23.7
1982	48.7	11.0	4.8	5.6	21.4
1983	41.8	9.1	4.1	4.8	18.1
1984	50.1	11.1	4.9	5.8	21.8
1985	49.1	11.5	4.7	5.6	21.7
1986	44.1	10.4	4.2	5.1	19.7
1987	43.0	10.2	4.0	4.8	19.1
1988	44.5	10.5	4.1	5.0	19.6
1989	44.9	10.6	4.1	4.8	19.6
1990	47.7	11.1	4.3	5.2	20.6
1991	47.3	11.3	4.2	5.0	20.5
1992	48.8	11.5	4.2	5.0	20.7
1993	49.2	11.4	4.4	5.1	20.9
1994	52.3	12.6	4.5	5.3	22.4
1995	50.7	11.7	4.4	5.1	21.3

[1] Includes Puerto Rico. Detailed State data shown in USDA, 1995. Fertilizer statistics used in this report include commercial fertilizers and natural processed and dried organic materials. Purchased natural processed and dried organic materials historically have represented about 1 percent of total nutrient use.

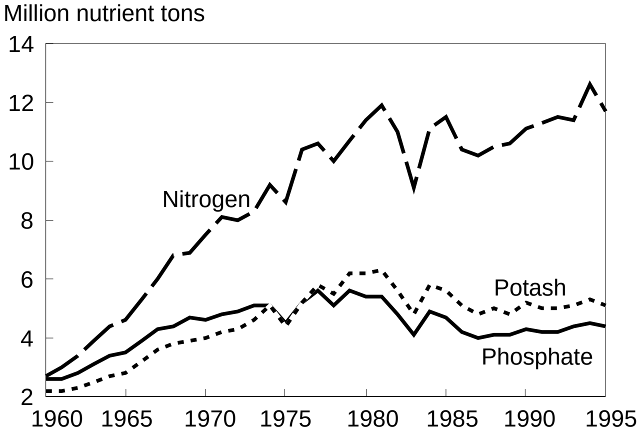
[2] Fertilizer use estimates for 1960-84 are based on USDA data; those for 1985-94 are Tennessee Valley Authority (TVA) estimates; those for 1995 are the Association of American Plant Food Control Officials estimates.

[3] Includes secondary and micronutrients. Most of the difference between primary nutrient tons and total fertilizer materials is filler material.

[4] Totals may not add due to rounding.

Source: USDA, ERS, based on Tennessee Valley Authority, *Commercial Fertilizers*, 1994 and earlier issues; USDA, *Commercial Fertilizers*, 1985 and earlier issues; Association of American Plant Food Control Officials, *Commercial Fertilizers, 1995.*

Figure 3.1.3--U.S. commercial fertilizer use, 1960-95



Source: Compiled by ERS from Tennessee Valley Authority, 1994 and earlier issues; Association of American Plant Food Control Officials, 1995.

increased farmer demand stemming primarily from favorable crop yield responses, especially corn, to nitrogenous fertilizers.

Phosphate's share of total commercial nutrient use declined from 34.5 percent in 1960 to 20.8 percent by 1995 (table 3.1.1). Potash use, historically below that of both nitrogen and phosphate, exceeded phosphate use for the first time in 1977 and will likely hold this position. In 1995, potash accounted for 24.0 percent of total fertilizer use.

Fertilizer products have changed over time. In 1960, mixed fertilizers (containing two or more nutrients) constituted almost 63 percent of total fertilizer consumption (Vroomen and Taylor, 1992). This share declined to 37 percent in 1995. The share of direct application materials (containing primarily one nutrient) increased from 37 percent to 63 percent during this period. The use of major direct-application nitrogen materials increased through the early 1980's (Fertilizer Institute, 1982). High-analysis products such as anhydrous ammonia, nitrogen solutions, and urea benefited from economies in transportation, distribution, and storage, and from the ease and accuracy of applying nitrogen solutions.

Directly applied phosphate fertilizer products have declined since the early 1970's because of the increased use of diammonium phosphate (DAP). The trend throughout the 1960's and 1970's was toward increased use of triple superphosphates (products that contained a higher percentage of phosphate) relative to normal superphosphates because of transportation, distribution, and storage economies. Since 1979, consumption of both normal and triple superphosphate has declined. The use of DAP, a mixed fertilizer containing 18 percent nitrogen and 46 percent phosphate, has dramatically increased since the 1960's (Tennessee Valley Authority, 1994).

The use of potassium chloride, the major directly applied potash fertilizer containing about 60 percent potash, has also greatly increased since the 1960's. Total use of potassium chloride reached 5.4 million tons in 1995, up from 389,000 tons in 1960.

Fertilizer Use by Region and Crop

The Corn Belt (Ohio, Indiana, Illinois, Iowa, and Missouri) uses more commercial fertilizer than any other region (table 3.1.2). Corn, the most fertilizer-using crop, historically has used around 45 percent of all fertilizer. However, from 1985 to 1993 nitrogen use in the Corn Belt decreased from 3.4 to 3.0 million tons, but then increased to 3.5 million tons in 1994 following the 1993 flood. Nitrogen use in the Corn Belt equaled 3.2 million tons in 1995. Phosphate use decreased from 1.5 million tons in 1985 to 1.3 million tons in 1995 and potash use decreased from 2.3 to 2.0 million tons. Fertilizer use is highly dependent on soil type and condition, crop mix, planting methods, and planted acres (Meisinger, 1984: Nelson and Huber, 1987: Mengel, 1986: Pierce and others, 1991: Rhoads, 1991: and Scharf and Alley, 1988). Fewer crop acres have been planted in the Corn Belt since 1981 because of government programs such as the Acreage Reduction Program (ARP) and the Conservation Reserve Program (CRP). Thus, total fertilizer use in the Corn Belt has declined even though application rates per fertilized acre and the proportion of acres treated have increased since the early 1980's. In the areas flooded in 1993, additional nutrients were applied in 1994 in excess of normal application rates to replenish flood-damaged soils. The Northern Plains region (North Dakota, South Dakota, Nebraska, and Kansas) is the second highest user of nitrogen and phosphate; nitrogen use increased from 1.8 million tons in 1985 to 2.1 million tons in 1995 (table 3.1.2).

Fertilizer use among crops differs significantly (Vroomen and Taylor, 1992; USDA, 1995). U.S. farmers use more commercial fertilizer on corn than on any other crop. Nearly all acres in corn, fall potatoes, and rice, and over three-fourths of cotton and wheat acres received some form of commercial fertilizer (table 3.1.3). The most frequently applied nutrient was nitrogen. In contrast, only 27-36 percent

Table 3.1.2—Regional commercial fertilizer use for year ending June 30, 1985-95[1]

Region	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
						1,000 tons					
Nitrogen:											
Northeast	312	278	290	278	313	306	299	328	350	376	349
Lake States	1,211	1,059	1,063	1,053	1,011	1,134	1,128	1,119	1,073	1,186	1,108
Corn Belt	3,443	3,116	2,889	2,991	3,041	3,215	3,280	3,279	3,003	3,562	3,228
Northern Plains	1,837	1,739	1,698	1,737	1,680	1,751	1,978	1,954	2,090	2,319	2,133
Appalachian	687	621	603	592	613	667	662	718	705	720	694
Southeast	720	659	665	614	643	670	627	655	682	701	640
Delta States	548	557	511	523	560	643	609	674	615	663	630
Southern Plains	1,110	965	1,022	1,204	1,217	1,117	1,223	1,192	1,235	1,377	1,208
Mountain	626	557	573	583	626	642	628	666	744	775	765
Pacific	987	860	882	924	916	921	838	849	886	953	953
U.S. total[2]	11,480	10,412	10,196	10,498	10,619	11,065	11,273	11,432	11,382	12,633	11,709
Phosphate:											
Northeast	229	196	203	193	188	197	188	208	211	232	203
Lake States	612	509	493	505	477	508	479	468	474	465	461
Corn Belt	1,478	1,380	1,255	1,303	1,254	1,334	1,262	1,269	1,312	1,317	1,257
Northern Plains	521	498	468	486	522	550	583	577	646	649	617
Appalachian	422	378	378	370	361	381	384	409	410	412	399
Southeast	331	288	300	280	297	308	281	295	314	297	313
Delta States	180	164	132	153	154	177	154	180	172	192	197
Southern Plains	364	298	305	324	342	315	334	288	340	363	341
Mountain	232	213	218	228	253	279	255	270	296	298	300
Pacific	288	250	250	281	270	289	274	248	257	291	326
U.S. total[2]	4,652	4,173	4,003	4,123	4,119	4,339	4,195	4,212	4,431	4,517	4,412
Potash:											
Northeast	288	263	253	249	232	261	262	267	262	299	280
Lake States	1,048	871	912	852	852	941	832	809	779	781	760
Corn Belt	2,264	2,165	2,020	2,126	1,974	2,132	2,044	1,987	2,034	2,133	1,996
Northern Plains	126	115	100	121	129	133	134	123	134	123	124
Appalachian	585	532	508	506	506	538	539	584	575	576	574
Southeast	607	542	524	531	558	559	517	556	581	535	563
Delta States	243	225	184	217	212	240	229	280	288	302	336
Southern Plains	169	142	133	140	149	143	150	146	168	191	168
Mountain	54	49	44	46	53	65	80	55	80	68	79
Pacific	157	137	146	171	155	179	200	220	230	252	231
U.S. total[2]	5,541	5,040	4,824	4,960	4,820	5,192	4,988	5,026	5,131	5,259	5,112

[1] Totals may not add due to rounding. Northeast = ME, NH, VT, MA, RI, CT, NY, NJ, PA, DE, and MD; Lake States = MI, WI, and MN; Corn Belt = OH, IN, IL, IA, and MO; Northern Plains = ND, SD, NE, and KS; Appalachian = VA, WV, NC, KY, and TN; Southeast = SC, GA, FL, and AL; Delta States = MS, AR, and LA; Southern Plains = OK, and TX; Mountain = MT, ID, WY, CO, NM, AZ, UT, and NV; and Pacific = WA, OR, CA, AK, and HA.

[2] Excludes Puerto Rico. Detailed State data shown in USDA, 1995.

Source: USDA, ERS, based on Tennessee Valley Authority, *Commercial Fertilizers*, 1994 and earlier issues; The Association of American Plant Food Control Officials, *Commercial Fertilizers, 1995*.

of the acres in soybeans, a nitrogen-fixing crop, received commercial fertilizer applications in 1995. Nitrogen application rates have been highest for fall potatoes, averaging 221 lbs. per acre in 1995, followed by corn (table 3.1.4). Fall potatoes also have the highest rate of both phosphate and potash applications, two to three times the rates for other major field crops. Nitrogen application rates on corn dropped from 132 lbs. per acre in 1986 to 129 lbs. per acre in 1995. In contrast, the average application rates increased for fall potatoes. The percentage of various crops receiving fertilizer, and fertilizer application rates, vary among the major growing States (USDA, 1995).

Table 3.1.3—Percent of acres receiving various nutrients, selected field crops in major producing States[1]

Crop, year	Manure	Commercial				Sulfur	Lime	Micro-nutrients
		Fertilizer	Nitrogen	Phosphate	Potash			
				Percent				
Corn for grain (10 States):								
1986	NA	96	95	84	76	NA	NA	NA
1987	16	96	96	83	75	3	2	5
1988	18	97	97	87	78	10	6	11
1989	15	97	97	84	75	8	5	11
1990	17	97	97	85	77	9	6	11
1991	19	97	97	82	73	10	4	11
1992	16	97	97	82	72	11	4	12
1993	18	97	97	82	71	10	4	11
1994	16	97	97	83	72	10	5	11
1995	14	98	97	81	72	NA	NA	NA
Cotton (6 States):								
1986	NA	80	80	50	39	NA	NA	NA
1987	3	76	76	47	33	7	1	9
1988	4	80	80	54	32	15	2	18
1989	2	79	79	54	32	21	2	15
1990	4	80	79	49	31	23	2	17
1991	3	81	81	52	34	20	2	18
1992	3	80	80	48	37	22	1	18
1993	4	85	85	54	36	23	3	18
1994	3	87	86	54	37	20	4	20
1995	3	87	87	56	40	NA	NA	NA
Fall potatoes (11 States):								
1989	4	99	98	94	83	48	7	52
1990	5	99	98	98	89	48	7	50
1991	4	99	99	98	88	52	4	56
1992	3	100	100	99	88	57	6	57
1993	4	100	100	98	91	58	6	58
1994	2	100	100	98	91	58	6	59
1995	2	100	99	98	89	NA	NA	NA
Rice (2 States):								
1988	1	99	99	46	36	7	NA	17
1989	*	99	99	46	33	5	NA	13
1990	*	98	97	36	37	13	1	14
1991	2	99	99	30	32	NA	2	11
1992	3	98	98	34	37	10	NA	9
Soybeans, Northern (7 States):								
1990	7	27	14	20	25	1	4	2
1991	6	26	14	19	22	1	4	2
1992	7	27	13	19	23	1	4	2
1993	7	26	12	18	24	1	4	2
1994	8	27	13	19	25	2	4	3
1995	5	27	16	19	23	NA	NA	NA
Soybeans, Southern (7 States):								
1990	2	41	26	38	39	4	6	5
1991	3	37	21	33	35	1	6	3
1992	2	39	22	36	37	2	8	1
1993	2	38	22	34	36	1	6	2
1994 (AR only)	2	37	17	32	34	1	4	2
1995	2	36	21	31	33	NA	NA	NA
All wheat (15 States):								
1986	NA	79	79	48	19	NA	NA	NA
1987	3	80	80	50	15	7	1	1
1988	2	83		83	53	18	6	1
1989	3	81	81	53	18	7	1	2
1990	2	79	79	52	19	7	1	2
1991	4	80	80	54	20	7	1	1
1992	3	84	83	56	18	8	1	2
1993	3	87	86	60	17	9	1	2
1994	3	87	87	59	17	10	1	2
1995	2	87	87	63	18	NA	NA	NA

Table 3.1.4—Average application rates of nutrients on selected field crops in major producing States[1]

Crop, year	Commercial nitrogen	Commercial phosphate	Commercial potash	Sulfur	Lime
			Pounds/acre		*Tons/acre*
Corn for grain (10 States):					
1986	132	61	80	NA	NA
1987	132	61	85	NA	NA
1988	137	63	85	11	1.9
1989	131	59	81	9	1.4
1990	132	60	84	11	1.6
1991	128	60	81	11	1.7
1992	127	57	79	11	1.9
1993	123	56	79	15	1.7
1994	129	57	80	12	1.7
1995	129	56	81	NA	NA
Cotton (6 States):					
1986	77	44	50	NA	NA
1987	82	44	45	NA	NA
1988	78	42	39	10	1.5
1989	84	43	40	23	1.3
1990	86	44	47	10	1.0
1991	91	47	48	12	1.0
1992	88	48	57	13	1.4
1993	89	47	58	13	1.0
1994	110	43	55	13	1.1
1995	95	43	51	NA	NA
Fall potatoes (11 States):					
1989	192	157	155	61	1.0
1990	198	163	143	57	0.9
1991	195	158	143	59	0.9
1992	200	159	147	61	0.9
1993	206	167	156	68	1.0
1994	264	192	184	82	0.9
1995	221	171	170	NA	NA
Rice (2 States):					
1988	127	47	50	19	NA
1989	125	45	45	17	NA
1990	114	45	49	11	1.0
1991	127	46	47	15	NA
1992	134	44	50	18	NA
Soybeans, Northern (7 States):					
1990	22	47	87	9	1.6
1991	24	49	80	12	2.0
1992	20	46	76	10	2.0
1993	18	47	83	15	1.5
1994	24	46	83	13	1.8
1995	27	55	91	NA	NA
Soybeans, Southern (7 States):					
1990	28	47	70	20	1.1
1991	28	45	70	12	1.2
1992	27	49	74	9	1.0
1993	24	44	70	22	0.9
1994 (AR only)	34	48	66	NA	1.3
1995	37	51	68	NA	NA
All wheat (15 States):					
1986	60	36	44	NA	NA
1987	62	35	43	NA	NA
1988	64	37	52	12	2.2
1989	62	37	46	12	1.9
1990	59	36	44	9	1.8
1991	62	36	43	11	1.4
1992	63	34	39	13	1.4
1993	64	34	35	14	1.7
1994	67	35	38	11	1.7
1995	65	33	38	NA	NA

[1] Data not available for manure or micronutrients. Major producing States generally account for 70-90 percent of each crop's acreage. For States included, see "Cropping Practices Survey" in the appendix. NA = Not available. Source: USDA, ERS, based on Cropping Practices Survey data.

Table 3.1.5—Manure and commercial fertilizer use by tillage type on corn for grain, 10 major States, 1990-95[1]

Crop, year	Acres receiving: Manure	Acres receiving: Commercial nitrogen	Acres receiving: Commercial phosphate	Acres receiving: Commercial potash	Average application rates: Commercial nitrogen	Average application rates: Commercial phosphate	Average application rates: Commercial potash
	Percent				*Pounds/acre*		
Conventional with plow							
1990	32	94	87	83	109	57	81
1991	35	94	85	79	106	56	77
1992	37	93	84	79	106	51	73
1993	39	95	89	84	95	54	76
1994	39	92	85	80	97	49	70
1995	38	93	83	71	96	50	66
Conventional without plow							
1990	14	97	85	78	138	61	84
1991	16	97	83	75	132	63	83
1992	15	97	84	74	129	58	81
1993	18	97	84	74	127	59	85
1994	16	97	84	74	133	60	84
1995	15	98	81	81	132	59	84
Mulch till							
1990	16	96	81	72	134	64	87
1991	18	97	78	68	130	59	78
1992	12	96	80	69	133	58	81
1993	15	96	81	68	122	57	75
1994	13	98	83	70	129	58	79
1995	14	97	83	70	134	57	75
No till							
1990	7	98	82	65	132	62	90
1991	10	98	81	67	129	59	84
1992	10	98	78	68	127	57	77
1993	10	98	83	73	122	50	71
1994	9	98	79	67	132	56	80
1995	8	98	79	65	134	56	76
Ridge till							
1990	20	100	96	49	145	32	52
1991	7	100	70	36	155	47	52
1992	6	99	96	33	143	41	50
1993	10	97	78	27	149	29	36
1994	2	99	78	38	142	37	57
1995	0	100	72	36	161	29	49

[1] States include IL, IN, IA, MI, MN, MO, NE, OH, SD, and WI.
Source: USDA, ERS, based on Cropping Practices Survey data.

The percentage of and quantity of crop acres receiving lime, sulfur, and micronutrients vary by crop (tables 3.1.3 and 3.1.4). For example, only about 1 percent of wheat acres received lime in 1994, while about 4 percent of northern soybeans and 6 percent of fall potatoes used lime. Lime application rates average between 1 and 2 tons per acre for all crops. Almost 60 percent of potato acres received an average of 82 pounds of sulfur in 1994. Other crops received between 11 and 18 pounds per acre with acres receiving sulfur ranging from 1 to 20 percent. Over 50 percent of potato acres received micronutrients.

Fertilizer use also varies by tillage system (tables 3.1.5-3.1.7). The Cropping Practices Survey data indicate lower nitrogen application rates on land using conventional tillage with plow for corn. These low applications appear to be supplemented with manure. For example, the average nitrogen application rate on

Table 3.1.6—Manure and commercial fertilizer use by tillage type on soybeans, 7 Northern States, 1990-95[1]

Crop, year	Acres receiving: Manure	Acres receiving: Commercial nitrogen	Acres receiving: Commercial phosphate	Acres receiving: Commercial potash	Average application rates: Commercial nitrogen	Average application rates: Commercial phosphate	Average application rates: Commercial potash
	Percent				*Pounds/acre*		
Conventional with plow							
1990	8	13	18	25	15	39	87
1991	10	14	18	20	31	53	86
1992	10	14	20	22	13	37	67
1993	9	12	17	22	13	43	82
1994	9	13	18	22	19	38	78
1995	3	16	14	14	11	53	80
Conventional without plow							
1990	7	16	23	28	24	50	83
1991	5	16	21	25	22	48	80
1992	5	13	22	26	18	46	75
1993	7	15	23	29	18	45	81
1994	9	13	20	25	26	44	78
1995	6	16	21	26	31	60	86
Mulch till							
1990	5	11	14	17	19	47	81
1991	6	13	15	17	23	46	76
1992	9	11	14	17	26	49	78
1993	7	9	12	16	15	44	84
1994	9	9	15	18	28	52	89
1995	7	13	14	16	27	57	92
No till							
1990	4	18	27	42	38	53	109
1991	4	11	18	24	28	56	89
1992	9	15	21	30	20	50	85
1993	5	13	22	31	20	52	87
1994	7	15	24	32	20	48	88
1995	3	18	23	29	26	51	97
Ridge till							
1990	20	12	21	30	19	48	109
1991	3	30	36	27	11	39	42
1992	8	26	21	18	26	16	5
1993	0	29	17	21	17	34	54
1994	0	36	31	27	10	20	43
1995	12	21	21	21	16	44	34

[1] Northern States include IL, IN, IA, MN, MO, NE, and OH.
Source: USDA, ERS, based on Cropping Practices Survey data.

corn acreage using conventional tillage with plow was 96 pounds per acre in 1995 compared with, say, 161 pounds for ridge-till land (table 3.1.5). However, 38 percent of conventional-till land using the moldboard plow received manure applications, compared with none for ridge-till.

Factors Affecting Fertilizer Use

Crop Acreage

As indicated, with application rates fairly constant, the total amount of fertilizer used has varied with crop acreage. Acreage of principal crops has varied over the years, ranging from 300 million acres in 1970 to 372 million acres in 1981. Since then, acreage has

Table 3.1.7—Manure and commercial fertilizer use by tillage type on winter wheat, major States, 1991-95[1]

Crop, year	Acres receiving				Average application rates		
	Manure	Commercial nitrogen	Commercial phosphate	Commercial potash	Commercial nitrogen	Commercial phosphate	Commercial potash
	Percent				*Pounds/acre*		
Conventional with plow							
1991	1	97	55	15	65	33	38
1992	2	94	53	13	74	34	37
1993	2	92	48	17	69	41	38
1994	1	95	63	10	63	34	61
1995	4	93	70	10	63	33	52
Conventional without plow							
1991	4	85	49	23	67	40	54
1992	3	87	49	22	67	38	49
1993	2	86	49	17	64	36	46
1994	2	87	49	13	66	37	49
1995	2	87	53	15	69	36	45
Mulch till							
1991	3	73	42	18	55	41	52
1992	1	71	36	16	51	33	39
1993	2	82	32	10	52	36	32
1994	4	67	25	9	55	31	43
1995	4	75	35	7	54	33	54
No till							
1991	6	84	70	48	71	48	75
1992	4	96	83	54	75	49	65
1993	3	95	82	59	80	49	67
1994	2	98	83	58	83	50	65
1995	2	93	76	52	79	56	69
Ridge till							
1991	nr	nr	nr	nr	nr	nr	nr
1992	nr	nr	nr	nr	nr	nr	nr
1993	nr	nr	nr	nr	nr	nr	nr
1994	nr	nr	nr	nr	nr	nr	nr
1995	nr	nr	nr	nr	nr	nr	nr

nr = none reported.
[1] States include AR, CO, ID, IL, IN, KS, MO, MT, NE, OH, OK, OR, SD, TX, and WA in 1991 and 1992. AR and IN not surveyed in 1993-95.
Source: USDA, ERS, based on Cropping Practices Survey data.

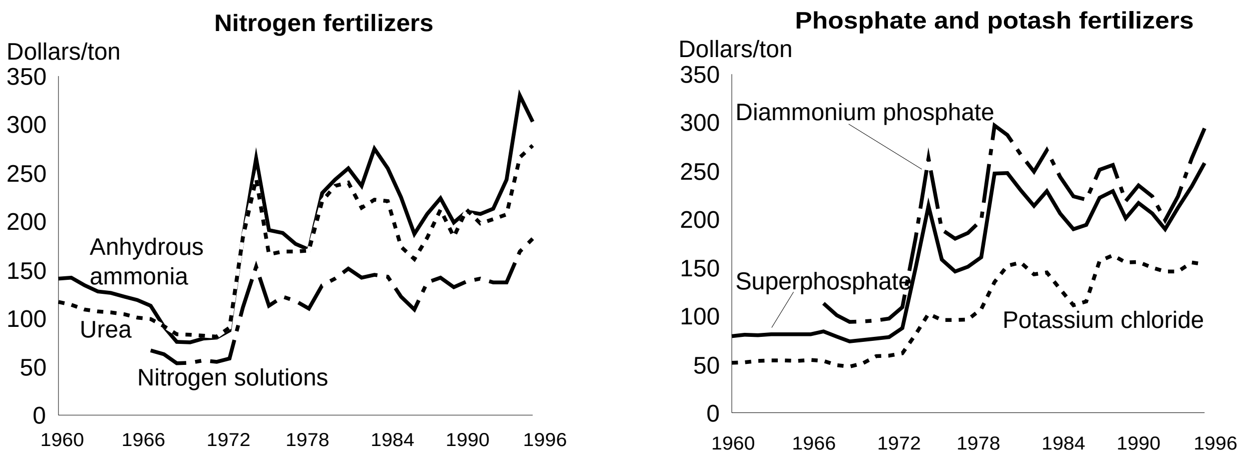
varied between 315 million and 340 million acres. In 1994, acreage of principal crops planted equaled 324 million acres.

Acreage and crop mix planted is dependent on many factors, including government programs, weather, expected commodity prices, input costs, and export market. Acres planted to corn and wheat greatly affect fertilizer use and prices. Corn is the most fertilizer-using crop, accounting for over 45 percent of all use, while wheat is second at 16 percent. Planted corn acreage has ranged from 60 to 85 million acres over the past 30 years and planted wheat acreage has ranged from 53 to 88 million acres. In 1994, approximately 79 and 70 million acres were planted to corn and wheat. To the extent that CRP and ARP acreage comes back into production as a result of contract expiration and higher crop prices, nutrient use could expand.

Fertilizer Prices

Fertilizer use in the United States has historically been inversely related but relatively unresponsive to changes in fertilizer prices, particularly in the short run. Analyses have found elasticities (the percentage change in fertilizer use per percentage change in fertilizer price) to run upwards from -0.19 in the short run and from -0.31 in the long run (after farmers have

Figure 3.1.4--Average farm prices of selected fertilizers, 1960-96



Source: USDA, ERS, based on USDA, NASS 1996 and earlier issues. See also table 3.1.8.

had adequate time to adjust operations) (Griliches, 1958; Denbaly and Vroomen, 1993). In some major Corn Belt States, the elasticities may be even less. One analysis of Indiana and Illinois data—using a model that allowed short- and long-run substitution among agricultural inputs (hired labor, feeds, seeds, fertilizer, pesticides, fuels, and capital) and that included a weather index—found elasticities of about -0.07 for corn both in the short and in the long run (Fernandez-Cornejo, 1993).

Individual fertilizer product prices vary from year to year and substitution among products within nutrient groups does occur. Annual price changes among products can result in different combinations of products used by farmers from year to year.

Fertilizer purchases have historically represented about 6 percent of total farm production costs. Total expenditures on fertilizer by U.S. farmers in 1994 are estimated at $9.1 billion, up 9 percent over 1993. The increase in expenditures is a combination of increased fertilizer prices, increased planted corn acres, and increased application rates over 1993. With current fertilizer prices, 1996 expenditures were likely to have exceeded those of 1994 and 1995.

Throughout the 1960's, prices paid by farmers for most fertilizer products declined as growth in industry capacity exceeded growth in demand (table 3.1.8, fig. 3.1.4). Economic Stabilization Program regulations froze all prices in 1971 to control inflation, including fertilizer prices at the producer level (USDA, 1971-81). Prices were controlled in domestic markets but exported materials were not subject to price regulation. Demand for U.S. fertilizer in strong-currency countries increased as the dollar weakened resulting in a two-price system for U.S. fertilizer, with export prices much higher than domestic prices. With the end of government control in 1973, domestic fertilizer prices increased over 60 percent and equaled world prices.

Decontrol and the oil embargo brought sharp increases in fertilizer prices. By the spring of 1975, farm prices of most fertilizer materials had doubled from 1973. High prices reduced the quantity demanded, causing fertilizer manufacturers' inventories to increase in 1976. Consequently, farm fertilizer prices fell. Prices began to rise again in 1979 following another oil embargo and as a result of strong domestic and export demand and rapidly rising production, transportation, and retailing costs. Rising energy prices in particular were instrumental in increasing production costs, especially for nitrogen products. Prices of most fertilizer products increased in 1980 and 1981 and held steady in 1982.

Fertilizer prices have changed less than other agricultural inputs during the last 10 years. For example, nominal prices farmers paid for fertilizers increased 18 percent from 1984 to 1995 while wage rates went up 51 percent, farm machinery increased 40 percent, agricultural chemicals other than fertilizers increased 28 percent, and seeds went up 16 percent.

Farm fertilizer prices fell during 1983 and again in 1985/86 as a record level of crop acreage was diverted, first by the payment-in-kind program (PIK)

Table 3.1.8—Average U.S. farm prices of selected fertilizers, 1960-96

Year[1]	Anhydrous ammonia (82% nitrogen)	Nitrogen solutions (30% nitrogen)	Urea (45-46% nitrogen)	Ammonium nitrate (33% nitrogen)	Ammonium sulfate (21% nitrogen)	Super-phosphate (20% phosphate)	Super-phosphate (44-46% phosphate)	Diammonium phosphate (18 percent nitrogen, 46 percent phosphate)	Potassium chloride (60% potassium)
	Dollars per ton								
1960	141	NA	117	82	58	38	79	NA	51
1961	142	NA	114	83	58	38	81	NA	52
1962	134	NA	109	82	57	38	80	NA	53
1963	128	NA	107	81	52	41	81	NA	54
1964	126	NA	106	80	53	40	81	NA	54
1965	122	NA	104	79	53	41	81	NA	54
1966	119	NA	101	77	53	41	81	NA	55
1967	113	67	99	74	54	42	84	113	54
1968	91	63	92	68	54	43	78	101	49
1969	76	54	84	62	53	44	74	94	48
1970	75	54	83	60	52	45	75	94	51
1971	79	56	82	63	52	48	77	96	58
1972	80	55	81	65	52	50	78	97	59
1973	88	58	90	71	55	54	88	109	62
1974	183	111	183	139	110	91	150	181	81
1975	265	153	244	186	148	118	214	263	102
1976	191	113	166	135	98	95	158	189	96
1977	188	122	169	141	101	99	146	180	96
1978	177	118	169	140	109	104	151	186	96
1979	171	110	170	138	118	109	161	199	107
1980	229	134	221	165	138	128	247	297	135
1981	243	141	237	185	150	134	248	287	152
1982	255	151	240	195	165	NA	230	267	155
1983	237	142	214	185	149	NA	214	249	143
1984	275	145	222	198	150	NA	229	271	145
1985	255	143	221	192	156	NA	206	244	128
1986	225	122	174	171	149	NA	190	224	111
1987	187	109	161	157	144	NA	194	220	115
1988	208	137	183	166	140	NA	222	251	157
1989	224	142	212	189	154	NA	229	256	163
1990	199	132	184	180	154	NA	201	219	155
1991	210	138	212	184	151	NA	217	235	156
1992	208	141	198	178	151	NA	206	224	150
1993	213	137	202	186	157	NA	190	199	146
1994	243	137	207	196	170	NA	212	224	146
1995	330	169	266	223	182	NA	234	263	155
1996	303	182	278	233	184	NA	258	294	153

NA = Not available.

[1] April prices for 1960-76, 1986-96; all other prices are for March.

Source: USDA, ERS, based on USDA, NASS, *Agricultural Prices*, 1961-96.

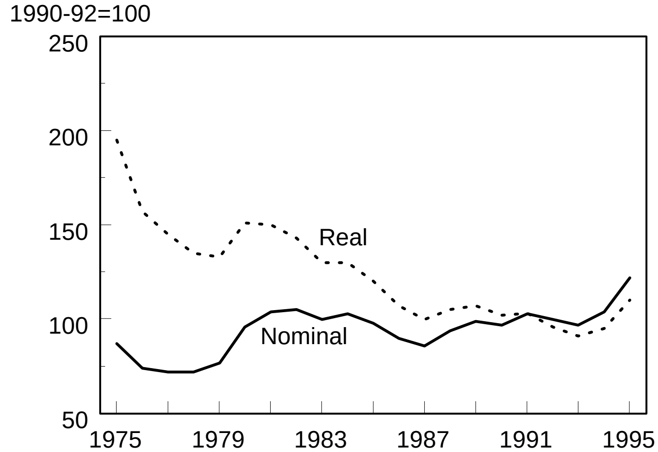
and later by the ARP and CRP programs and excess supplies (Vroomen and Taylor, 1992). Prices rose steadily from 1986 to 1989. Prices of most fertilizer materials have fallen from 1989 levels, but remained relatively stable through 1992 (Taylor, 1994). Prices paid by farmers for fertilizer in 1994-96 increased over 1993 prices due to increased planted acres and other market conditions.

The prices U.S. farmers currently pay for many fertilizer materials have risen significantly since 1993. For example, the price of anhydrous ammonia increased 64 percent from October 1993 to April 1995 to a record high of $330 per ton. Diammonium phosphate's price increased 37 percent over this time period. Other fertilizer products also increased, but not as much. Real fertilizer prices (fertilizer price index adjusted by the implicit price deflator of the United States) have declined from an index of 195 in 1975 to 110 in 1995 using 1990-92 as a base (fig. 3.1.5). In constant dollars, farmers paid 44 percent less for fertilizer in 1995 than they did in 1975.

The increase in fertilizer prices since 1993 is a result of tight world supplies and increased demand. For example, anhydrous ammonia use increased 26 percent from 1993 to 1994, and total nitrogen use increased over 11 percent due to an increase in corn acres (corn uses about 45 percent of all fertilizer). Increases in planted acres of soybeans, cotton, and rice also contributed to an increased demand for fertilizer. Nitrogen application rates on corn increased from 123 to 129 pounds per acre in 1994-95 following the 1993 flood; phosphate and potash application rates also increased. In addition, weather conditions were ideal for the direct application of anhydrous ammonia. There was also an increase in nonagricultural demand for nitrogen in products such as adhesives, plastics, resins, and rubber. During 1995, U.S. fertilizer exports increased over 1994 because of China's increased demand for diammonium phosphate and other fertilizer products.

On the supply side, several factors placed upward pressure on fertilizer prices during 1994 and 1995, including higher priced imports from the former Soviet Union, unscheduled repairs that caused plant closings, low inventories, and an explosion that temporarily closed a large nitrogen production plant. The United States is a net importer of ammonia. Since 1990, U.S. ammonia demand has exceeded U.S. supplies while nitrogen plants have been producing in excess of 100 percent capacity. These factors have occurred during a period in which both agricultural and industrial demands have been growing and ammonium phosphate exports have risen.

Figure 3.1.5--Index of prices paid by farmers for fertilizer



Source: USDA, ERS, based on USDA, NASS 1995 and earlier issues.

Commodity Programs

Commodity programs can directly influence fertilizer use through planted acreage or application rates. The U.S. Government supported crop prices for over half a century by lending farmers money at varying loan rates, using crops as collateral and guaranteeing minimum crop prices (target prices set by law). When market prices of commodity program crops were lower than target prices, participating farmers could receive from the Government deficiency payments for crops planted to base acreage. Deficiency payments were the difference between the target price and the higher of the loan rate or average market price. Participation in commodity programs provided farmers with a more stable farm economy over time; however, participation also required some land to be idled (CRP and ARP programs). Data from the 1991 and 1992 Cropping Practices Survey were analyzed to determine if economic incentives from participation in commodity programs caused program participants to apply fertilizers at greater rates than nonparticipants (Ribaudo and Shoemaker, 1995). Fertilizer and agricultural chemical use between corn grower program participants and nonparticipants were analyzed. The results of that study suggest that economic conditions created by commodity programs increased fertilizer application rates on corn. Future fertilizer use is uncertain. If farm and trade policy continues to provide farmers with more acreage flexibility and freer market

Potential for Agricultural Use of Municipal Wastes

Many urban areas in the United States have an urgent need for a long-term environmentally safe method for recycling and disposal of municipal wastes. Currently the number of landfills is limited and new landfills that meet EPA standards for protecting the environment are costly. Municipal wastes contain nutrients and organic matter and other soil conditioners that can be used for agriculture which could mitigate urban waste disposal problems and their economic costs. The fertilizer-equivalent value to U.S. farmers of municipal solid wastes (MSW) is about $378 million and sewage sludge (SS) is about $72 million. Nutrients from the wastes could reduce dependence on commercial fertilizer from limited supplies of mineral and energy resources. Wastes are being used in the horticultural industry; greater use in agriculture would contribute to the long-term sustainability of agricultural production.

One promising way to use municipal wastes is through composting, a microbiological process that partially decomposes organic wastes through the growth and activity of bacteria, actinomycete, and fungi that are indigenous to the organic wastes. The process reduces the weight and volume of the waste while abating odors, destroying pathogens, and converting nutrients to more plant available forms.

Issues

Technical, economic, and public perception issues hinder agricultural use of municipal wastes. Research is underway to provide better information. Technical issues to be resolved include: (1) uncertainty about the quality of municipal wastes because of heterogeneity and range in chemical and physical characteristics of wastes; (2) concern about the fate and effects of trace elements, synthetic organics and pathogens in wastes on soils, plants, animals and humans; (3) uncertainty about application methods and levels of waste applied to agricultural or horticultural production systems to minimize damage to the environment, such as the accumulation of non-nutrient heavy metals in soils; and (4) inadequate information on blending, mixing, or co-composting different wastes to produce final products with desirable characteristics for agricultural or horticultural use.

Economic issues include: (1) uncertainty about the fertilizer equivalent and soil-conditioning value of municipal wastes; (2) economic application to land; (3) the extent to which municipalities may need to subsidize waste transportation expenses to make its use economically feasible in agricultural production. Public perception issues include the need to show that agricultural use of municipal wastes is environmentally safe and does not pose a human health risk.

Sources: USDA, ERS, based on ARS, 1993; Goldstein and others, 1994; and EPA, 1993.

conditions, fertilizer use could increase as more acres come into production. At the same time, possible declines in commodity prices could reduce the demand for fertilizer.

Increased Nutrient Management

Over 1,400 counties contain areas where groundwater is susceptible to contamination from agricultural pesticides or fertilizers (National Research Council, 1989). States including California, Florida, Iowa, Nebraska, New York, and Wisconsin have developed strategies for dealing with agriculturally induced groundwater contamination. Contamination is prevalent in areas with sandy soils, which are highly porous. In some of these areas, restrictions have been placed on fall applications of nitrogen-based fertilizers. Applications are restricted either under certain weather conditions or during certain time periods. In ammonium form, nitrogen is fairly immobile in soil. Under most conditions, however, ammonium is converted biologically to nitrate, which readily moves with the soil water. Nitrate that is applied in the fall when no crop is planted or when plant uptake is minimal has greater potential of moving with the soil water from the soil to groundwater, streams, and impoundments. Otherwise, it denitrifies and passes to the atmosphere as gas. Effective timing of split fertilizer application during the crop-growing season and the use of nitrification inhibitors can reduce nitrate leaching and denitrification and improve crop nutrient uptake. Efforts to improve nitrogen efficiency will require better synchronization between soil nitrogen availability and crop nitrogen requirements.

A wide variety of nitrogen fertilizer formulations are available to producers to accommodate various times, rates, and methods of application. Additional nitrogen management may be required to minimize contamination of groundwater. Management systems that hold promise include the use of satellite imagery or Global Positioning Systems and grid farming, which allow nitrogen management by soil variation rather than by field. For more discussion of nutrient management, see chapter 4.5.

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Recent ERS Reports on Nutrient Issues

1995 Nutrient Use and Practices on Major Field Crops, AREI Update, May 1996, No. 2 (Harold Taylor). Total nutrient use was 5 percent lower in 1995 than in 1994 with nitrogen use down 7 percent and phosphate and potash use down about 2 percent each. The major factor was decreased corn acreage, which uses 40-45 percent of all fertilizer.

Agricultural Input Trade, AREI Update, 1995, No 10. (Stan Daberkow, Mohinder Gill, Harold Taylor, Marlow Vesterby). The United States is a major exporter of phosphate and nitrogen fertilizer products and a major importer of potash. The value of fertilizer exports has varied from $3.0 billion in 1991 to $1.8 billion in 1993. Data are reported by region and country.

Pesticide and Fertilizer Use and Trends in U.S. Agriculture, AER-717, May 1995 (Biing-Hwan Lin, Merritt Padgitt, Len Bull, Herman Delvo, David Shank, and Harold Taylor). Pesticides and fertilizer contribute to increased productivity in agriculture, but their use is also associated with potential human health, wildlife, and environmental risks. Nitrogen, phosphate, and potash all shared in the dramatic increase in fertilizer use, but the relative use of nitrogen increased much more rapidly from 37 percent of total nutrient use in 1960 to more than 50 percent since 1981.

Chemical Use Practices, RTD Update, July 1994, No. 2 (Harold Taylor, Biing-Hwan Lin, and Herman Delvo). Chemical application timing and methods varied considerably among the major field crops. Fertilizer was more frequently applied before planting to corn, soybeans, and winter wheat, at planting to durum and spring wheat, and after planting to cotton and fall potatoes. Herbicides were most frequently applied after planting to most crops except upland cotton. Area and State-level data are for corn; upland cotton; fall potatoes; soybeans; and winter, spring, and durum wheat.

Fertilizer Use and Price Statistics, SB-893, Sept. 1994 (Harold Taylor). The rapid growth in fertilizer consumption throughout the 1960's and 1970's peaked at 23.7 million nutrient tons in 1981. Use remained relatively stable, ranging from 19.1 to 21.8 million tons during 1984-93. Fertilizer prices vary by product and year, but the fertilizer price index was less during the late 1980's and early 1990's than in 1982. Area and State data are for corn, cotton, soybeans, and wheat from 1964-1993, and total U.S. consumption data are from 1960 to 1993.

(Contact to obtain reports: Harold Taylor, (202) 219-0476 [htaylor@econ.ag.gov])

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Glossary

Ammonium nitrate: A prilled or granulated product containing not less than 33 percent nitrogen, one half of which is in the ammonium form and one half in the nitrate form.

Ammonium sulfate: Soluble in water and contains 21 percent nitrogen and 24 percent sulphur. It is usually made by treating bauxite with sulfuric acid. It is applied to western soils to make them less alkaline.

Anhydrous ammonia: A colorless, pungent gas containing 82.25 percent nitrogen and 17.75 percent hydrogen, which can be liquefied and transported at normal temperatures in high-pressure cylinder tanks, and injected under pressure into the soil or mixed with irrigation water.

Available nutrients: That part of fertilizer supplied to the plant that can be taken up by the plant.

Blended fertilizer: A mechanical mixture of two or more fertilizer materials.

Diammonium phosphate (DAP): A product made from wet process phosphoric acid and ammonia containing 18 percent nitrogen and 46 percent phosphate.

Economically recoverable manure: The excreta of animals (dung and urine) mixed with straw or other materials that can be economically recovered and used as a fertilizer.

Guano: Partially decomposed excrements of birds, bats, seals, or other animals.

Inorganic fertilizers: Fertilizer materials in which carbon is not an essential component of its basic chemical structure.

Lime: A soil conditioner consisting essentially of calcium carbonate, calcium oxide, calcium hydroxide, magnesium carbonate, magnesium oxide, or a combination of these capable of neutralizing soil acidity.

Micronutrients: Boron, chlorine, cobalt, copper, iron, manganese, molybdenum, sodium, and zinc are needed only in small amounts. They contribute to cell division, photosynthesis, fruit formation, carbohydrate and water metabolism, chlorophyll formation, protein synthesis, and seed development.

Mixed fertilizers: Two or more fertilizer materials mixed or granulated together into individual pellets.

Muriate of potash (potassium chloride): A potash salt of hydrochloric acid (muriatic acid) containing 60-62 percent soluble potash.

Natural organic fertilizers: Materials derived from either plant or animal products containing one or more elements (other than carbon, hydrogen, and oxygen) essential for plant growth.

Nitrogen solutions: Solutions of nitrogen fertilizer chemicals in water. Urea ammonium nitrate (UAN) solutions are made from a mixture of urea and ammonium nitrate and contain 28-32 percent nitrogen.

Primary Nutrients:

Nitrogen (N) is an essential element in the production of food protein by the plants and in the conversion of carbon dioxide in the air and water into carbohydrates through photosynthesis. It also is essential for vigorous plant growth and for obtaining high crop yields. Principal forms of nitrogen fertilizer are anhydrous ammonia, urea, ammonium nitrate, and nitrogen solutions.

Phosphate (P_20_5), the oxide form of phosphorus (P) is vital to plant growth playing a key role in photosynthesis, respiration, energy storage and transfer, cell division, cell enlargement, genetic coding, and many other plant processes. An adequate level of phosphate provides rapid, extensive growth of young plant roots. Principal forms of phosphate fertilizer are normal and superphosphate, and diammonium phosphate.

Potash (K_20), the oxide form of potassium (K) activates many enzyme systems in the plant and helps the plant use water more efficiently with less loss. It is essential for varied process-photosynthesis rates, product formation, winter hardness, and disease resistance. It stops stalks from lodging, preventing a decrease in crop yields. Principal forms of potash fertilizer are potassium chloride, potassium sulfate, and potassium nitrate.

Secondary Nutrients: Calcium, magnesium, and sulfur are essential to plant growth in lesser quantity than nitrogen, phosphate, and potash but in greater quantity than micronutrients.

Sewage sludge: Solids removed from sewage by screening, sedimentation, chemical precipitation, or bacterial digestion.

Sodium nitrate: Sodium salt of nitric acid containing not less than 16 percent nitrate nitrogen and 26 percent sodium.

Superphosphate: Products obtained when rock phosphate is treated with either sulfuric acid or phosphoric acid or a mixture of these acids. Normal superphosphate contains up to 22 percent phosphoric acid. Enriched superphosphate contains more than 22 percent but less than 40 percent phosphoric acid. Concentrated or triple superphosphate contains more than 40 percent phosphoric acid.

Urea: A white crystalline or granular solid synthesized from ammonia and carbon dioxide under high temperature and pressure and containing not less than 45 percent nitrogen.

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